LA-UR-21-24061

Approved for public release; distribution is unlimited.

Title: Stagger Tuning Summary

Author(s): Ekdahl, Carl August Jr.
Mccrady, Rodney Craig

Intended for: Report

Issued: 2021-04-27

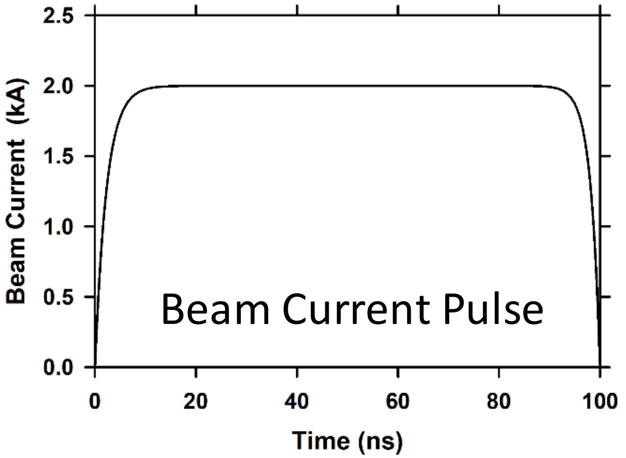
Stagger Tuning Summary

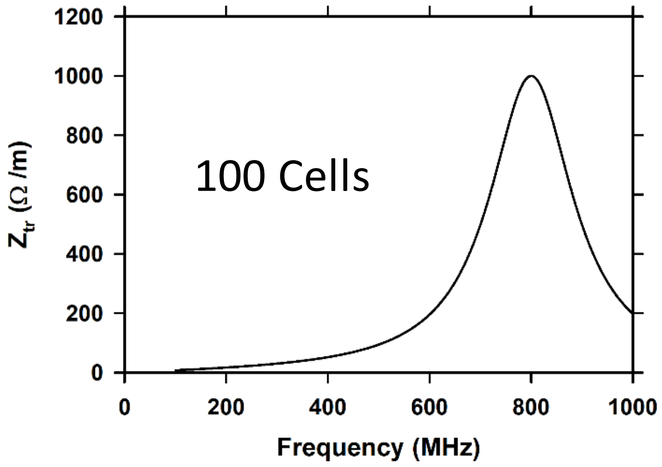
Carl Ekdahl and Rodney McCrady

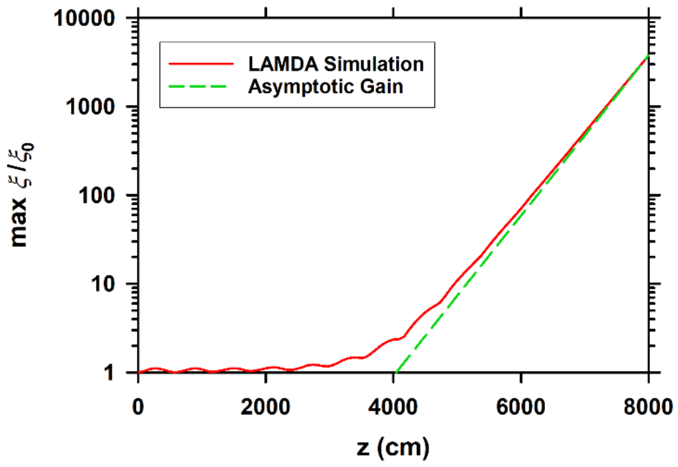
Summary of "Suppression of Beam Breakup in Linear Induction Accelerators by Stagger Tuning," by Carl Ekdahl, and Rodney McCrady, which appeared in the October, 2020 issue of *IEEE Transactions on Plasma Science*:

- **Beam Breakup (BBU) is dangerous for high-current linear induction accelerators (LIA) used for flash radiography. Cavity mode RF is coupled to the beam. For frequencies lower than the beam-pipe cutoff, the cavities only communicate via RF on the beam. This cumulative mode BBU grows exponentially with a number of e-foldings proportional to (Number of cavities) X (Beam current) X (Coupling factor) / (Magnetic focusing field).**
- **Coupling to a cavity is characterized by wake potential of a point charge traversing the gap, which can be thought of as the Greene's function for the coupling. In the time domain, coupling to a current pulse is the convolution of the pulse waveform with the point-charge wake potential. In the frequency domain it's the product of Fourier transforms. The transform of a point-charge wake potential is the coupling factor known as the transverse impedance, Z_{tr}.**
- **The theoretical growth asymptotes to $\xi / \xi_0 \propto \exp(\Gamma)$, with $\Gamma = N_{cells} I_{beam} Z_{tr} \langle 1/B_z \rangle / c$**
- **A means for suppressing BBU is to alternate cells with different impedances -- so-called "stagger tuning." The beam samples the different impedances, so the BBU growth depends on the average. If the impedances have much different resonant frequencies, this average "effective" impedance can be much less than either, resulting in substantially less growth.**
- **The DARHT-I LIA at Los Alamos achieves a natural stagger tuning, because its cavities are asymmetric, so they have different impedances for beam oscillations in the horizontal and vertical planes. The Larmor rotation of these planes in the axial B-field causes the beam to average the two, thereby presenting an effective impedance less than would be the case for symmetric cavities.**

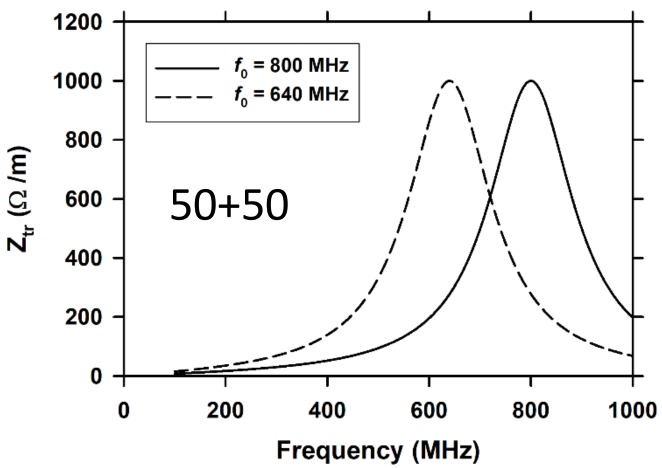
- **Beam Breakup (BBU) is dangerous for high-current linear induction accelerators used for flash radiography.**

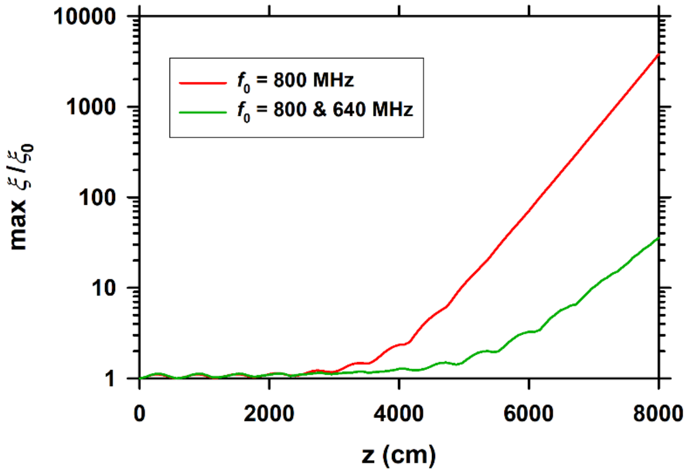




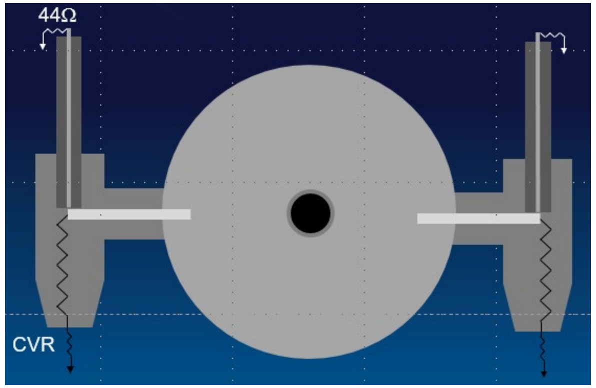


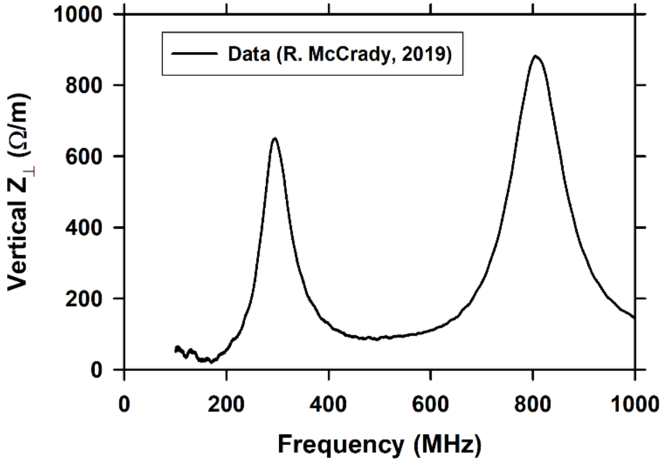
- **A means for suppressing BBU is to alternate cells with different impedances -- so-called “stagger tuning.”**

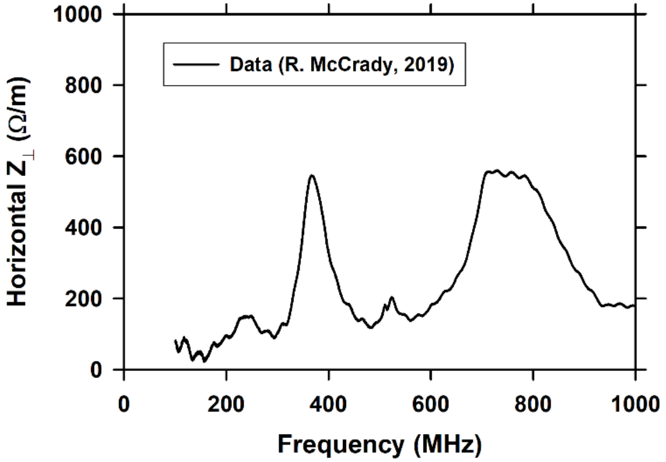




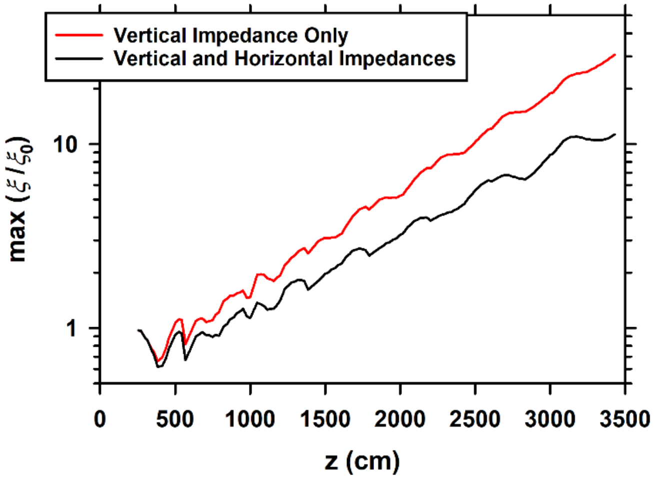
- **DARHT-I cells have a natural asymmetry due to drive rods. Vertical plane impedance is unaffected, but horizontal plane impedance is strongly attenuated. These impedances have recently been measured with unprecedented accuracy.**







- **Larmor rotation of the plane of BBU oscillations causes beam to sample both impedances, resulting in stagger tuning with an effective impedance that is an average of the two, which is less than for a symmetric cell.**



BBU calculated by a code incorporating both impedances and Larmor rotation shows that the reduction of growth is the same as for a single impedance that is the average.